WATER

HYDROLOGICAL DATA

GROUND WATER & PERMAFROST

AT BETHEL, ALASKA

ALASKA DEPT. OF HEALTH

SECTION OF SANITATION & ENGINEERING

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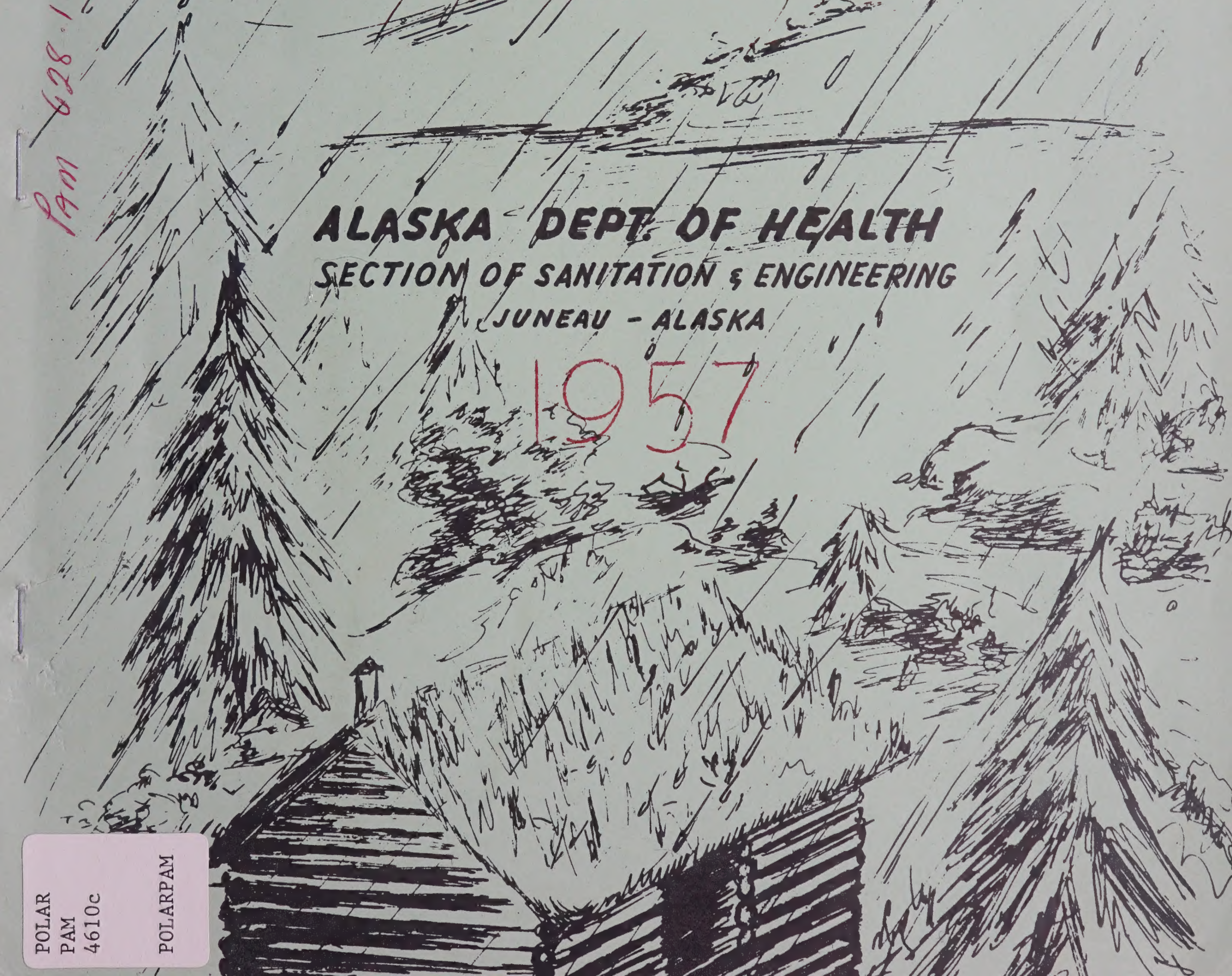

UNITED STATES
DEPARTMENT OF THE INTERIOR
Geological Survey

GROUNDWATER AND PERMAFROST AT BETHEL, ALASKA

By

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1957

Prepared in cooperation with the Alaska Department of Health

Open--file report. Not reviewed for conformance with standards and nomenclature of the Geological Survey.

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BETHEL WATER SUPPLIES

Bethel, located on the northwest bank of the Kuskokwim River in southwestern Alaska has had a turbulent history insofar as its domestic water supply is concerned. A review of the records for this area reveals the best, though, in public health relations and assistance by the Alaska Department of Health in preserving minimal standards under adverse conditions. Active participation by other agencies such as the U. S. Geological Survey, Arctic Health Research Center, Alaska Native Health Service and practically all Territorial agencies have had a hand in the environmental health improvements in this village.

As a result, the domestic water supply status in Bethel is presently encouraging. Ground water exploration has produced water from thirteen wells at various depths and yielding amounts ranging from meager to moderately large depending upon the nature of the unfrozen sedimentary formation underlying the area.

Details concerning ground water, permafrost and Geology are hereby presented quite thoroughly by Mr. R. M. Waller of the U. S. Geological Survey in cooperation with the Alaska Department of Health.

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GROUND WATER AND PERMAFROST AT BETHEL, ALASKA

INTRODUCTION

This report is a result of a study of the results of a test-drilling program conducted by the Alaska Department of Health to determine whether a ground-water supply is available in the village of Bethel, Alaska. The U. S. Geological Survey was asked to assist in evaluating the available information on the geology, the ground-water possibilities at the village, and the results of drilling a deep test well, as part of the program of determining the ground-water resources of Alaska.

There has been little ground-water development in the part of Alaska that includes the Bethel area, and very little was previously known of ground-water conditions there. Cederstrom (Cederstrom, D. J., 1952, Summary of Ground-Water Development in Alaska, 1950: U. S. Geol. Survey Circ. 169, p. 29-30) summarized the information available for the village of Bethel as of 1950. At that time the villagers were using the Kuskokwim River for their water supply, and that use has continued to the present.

This report describes the subsurface materials and ground-water conditions at Bethel (fig. 1) and in the immediate vicinity as interpreted in the light of recent drilling of an Alaska Department of Health test well (no. 14 in this report). The area surrounding the village was included in the investigation because of the information available on existing wells and test holes drilled in that area. The files of the Ground Water Branch of the Geological Survey at Anchorage contained records of a few of the wells and test holes drilled prior to the time of this investigation (see fig. 2 for well and test-hole locations). Additional water samples were obtained and analyzed at the laboratory of the Geological Survey at Palmer, Alaska, to supplement the analyses already on file. Supplementary well information was kindly furnished by the following: Project Engineer at the U. S. Air Force Station, Resident Engineer at the Alaska Native Health Service Hospital, Mr. Clarence Marsh of the Alaska Road Commission, Bethel, Mr. Schmidt, local water purveyor, and Mr. Elmer Nicholson, Northern Consolidated Airlines, Inc. bush pilot.

GEOGRAPHY

Bethel is on the northwest bank of the Kuskokwim River in southwestern Alaska (fig. 1), about 400 miles west of Anchorage. The village is in the southeastern part of the vast delta formed by the Yukon and Kuskokwim Rivers which empty into the Bering Sea, and lies about 60 miles north of the mouth of the Kuskokwim River. The surface of the delta has a low relief; the nearest land having substantial relief is the Kilbuck Mountains, about 40 miles to the east and southeast. The numerous channels of the Kuskokwim River and of its tributaries meander over much of the delta east and northeast of Bethel. To the west, the land is slightly higher and the gently rolling surface is dotted with numerous ponds and small lakes.

The Bethel area is subject to annual flooding during the spring "breakup". The village does not become inundated, but the floodwaters usually crest over the river bank in a few places. The airport south of the river

Figure 1. — Map showing location of Bethel, in southwestern Alaska

Figure 2 Well locations in the Bethel Area, Alaska.

(see fig. 2) is flooded nearly every year.

The climate at Bethel is more marine than continental. The expanse of flat land extending about 100 miles west and southwest to the Bering Sea permits marine weather to move uninterruptedly toward (and through, as the local residents exclaim) Bethel. Wind velocities exceeding 70 miles per hour are not uncommon during storms. The annual average temperature is about 30° F. The average low temperature for January, the coldest month, is 6°. July, the warmest month, has an average high of 55°. Annual precipitation averages 19 inches, August being the wettest month. Snowfall averages 50 inches per year.

At present, the village has a population of about 900, excluding that of the Alaska Native Health Service (formerly Alaska Native Service) Hospital, henceforth called ANHS, about a mile west of the village. Transportation is furnished to Bethel daily by two airlines, and the Alaska Steamship Line serves the area once or twice each summer. A new airfield is being constructed, 2½ miles west of the village, by the Territorial Department of Aviation to replace the annually flooded airport east of the river. A U. S. Air Force station is under construction about 5 miles west of the village.

GEOLOGY

Sedimentary material of unknown thickness underlies the Bethel area. Clay, silt, sand, and some gravel have been encountered in all wells drilled in the area. The deepest well reached a total depth of 433 feet. The logs of the wells indicate that the material encountered generally becomes progressively coarser with increased depth. The upper, finer-grained sediments probably were deposited from streams that transported the material a long distance. The deeper, coarser material is thought to have been transported from a closer source, or else the former streams had a steeper gradient or greater flow, which enabled them to carry coarser material. The coarse sand and fine gravel reported in a few of the wells cannot be correlated from one well to another. The coarser deposits, apparently lenticular, usually are overlain with wood chips, bark, and other organic material.

PERMAFROST

The Bethel area is near the southern boundary of the zone of permanently frozen ground (permafrost). The permafrost apparently influences the occurrence and growth of the vegetation in the area. The village, and presumably almost the entire area west of the river, are underlain by permafrost, which extends 377 feet below the surface at well 14 (see log). The land is covered by tundra and is almost devoid of trees. However, east of the river and on a few low spots along the west side, the area seems to be essentially free of permafrost to a depth of at least 197 feet (see well 3), and willows and small shrubs predominate. Apparently, the permafrost has thawed in local areas on the west side where there are, or have been, streams or other large bodies of water, such as near the slough (fig. 3) and on the airport (east) side of the river (fig. 4) the permafrost has been completely (?) thawed by the Kuskokwim River. The surficial sediments east of the river were deposited over the thawed subsurface deposits relatively recently, and the ground has not had sufficient time to freeze deeply again.

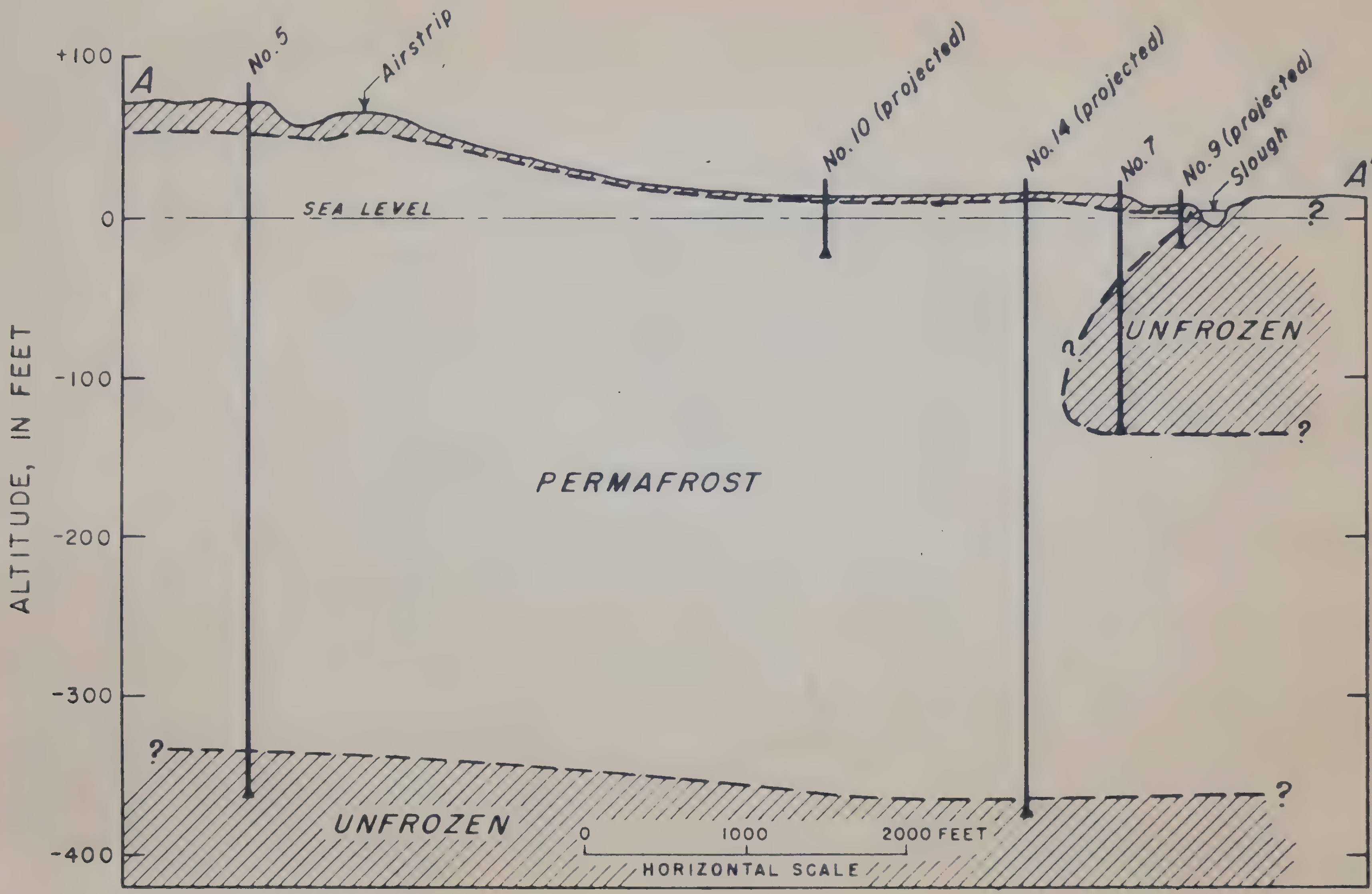

Figure 3. — Section A-A' showing the extent of permafrost.

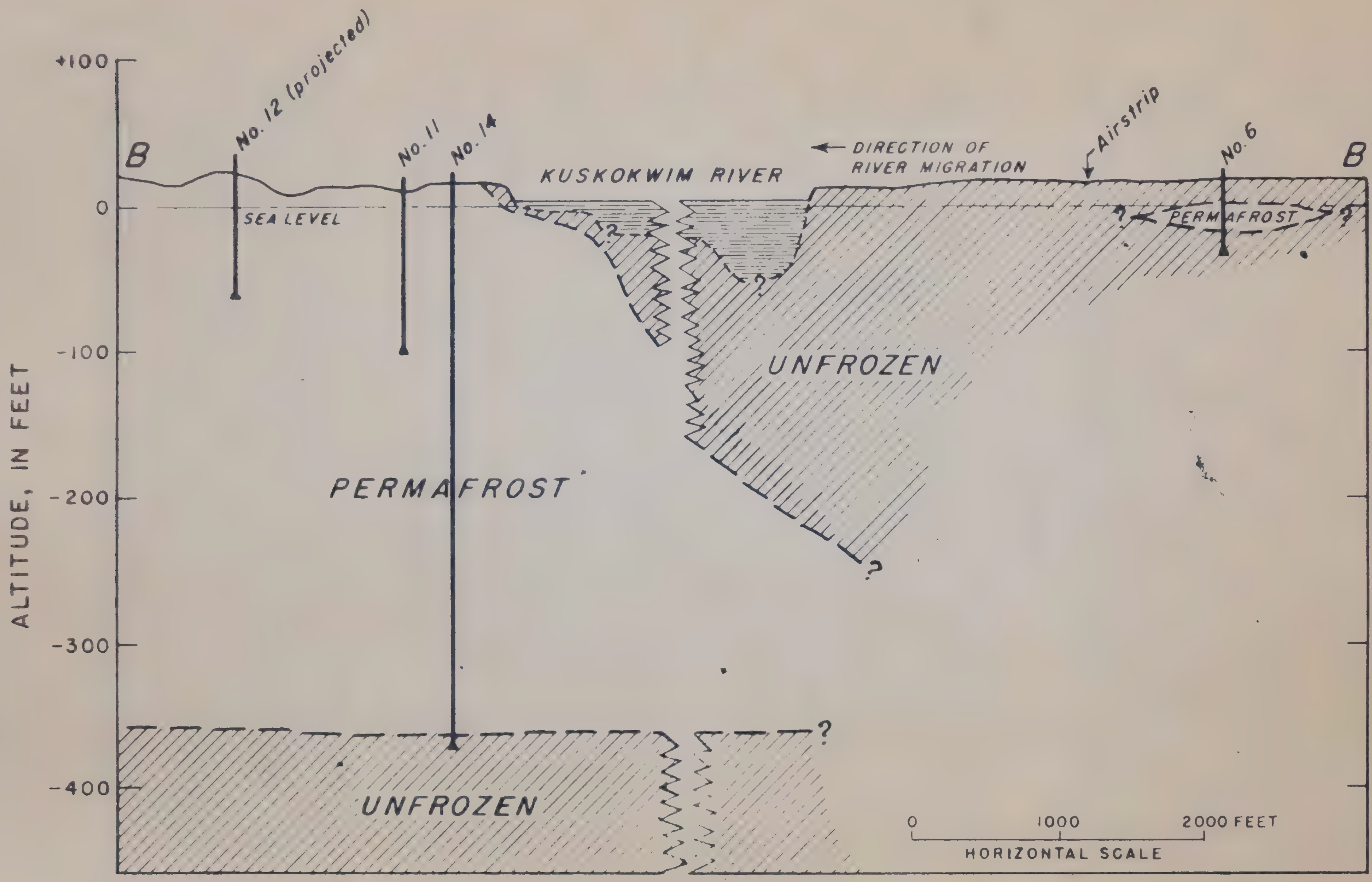

Figure 4. — Section B-B' showing the extent of permafrost.

The river has been gradually eroding the bank along the outer edge of the meander loop where the village is located. Local inhabitants report that, although there has been very little erosion in the past few years, the river has cut about 40 feet into the village in the past 20 years. This recent migration of the river offers an explanation for the occurrence of permafrost to and under the outside edge of the meander loop of the river (see fig. 4). The well at the ANHS hospital (No. 5), on higher ground, presumably reached the bottom of the permafrost at 403 feet. The elevation of the bottom of the permafrost (333 feet below sea level) in this well is comparable with that in the Alaska Department of Health (ADH) well, No. 14 (360 feet below sea level, see fig. 3).

The well at the Air Force station, no. 13, although not in the immediate area of this report, has been included because it adds additional information on subsurface conditions in this part of Alaska. The well is in a valley adjacent to the station. The station, some 80 feet higher than the well site, is underlain by perennially frozen ground to at least 36 feet (depth of borings to set pilings); whereas, at the well site in the valley, frozen ground was reported in the interval from 22 to 42 feet, and from 280 feet to the bottom of the well at 378 feet (see log). However, the existence of the frozen zone, reported between 22 and 42 feet was considered questionable by the station project engineer. Also, the 180-foot test hole (No. 2) drilled probably about 1948 at this same site was reported to be entirely free of permafrost. Consequently, the 22-42-foot frozen zone could be considered one of three things, (1) a misinterpretation by the driller, (2) the upper part of the permafrost beneath which is a thawed layer (talik) of great thickness, or (3) a local regrowth of permafrost. The writer believes that the absence of extensive frozen ground in this well is due to a stream (ancient Kuskokwim River) which apparently flowed here long enough to form the shallow valley and to thaw the permafrost beneath the valley to 280 feet, before being diverted to another channel. The Air Force well bottomed in frozen ground at -265 feet, some 100 feet higher than the bottom-hole elevation of the ANHS well (-363 feet) and the ADH well (-373 feet), both of which bottomed in unfrozen ground. Hence, it is not known whether the base of the permafrost would have been encountered at about 350 feet below sea level in the Air Force well as it was in the other two wells.

GROUND WATER

Ground water is available in amounts ranging from small to moderately large depending on the coarseness of the material in the unfrozen sedimentary materials underlying the area. In the main part of the village, and to the west and southwest, the underlying sediments are permanently frozen except for a very shallow seasonally thawed zone (active layer) at the surface and occasional taliks near the surface. Therefore, most wells must be drilled through nearly 400 feet of frozen sediments before encountering unfrozen water-bearing material. Data from two test holes started near the slough at the east edge of the village (fig. 3) indicate that there are taliks in that area which contain water. However, the material encountered (see log of well 7) is very fine grained and a fine-mesh screen and careful development would be required to produce a satisfactory well. Near-surface unfrozen zones were encountered also at Hangar Lake (see well 8). These shallow unfrozen zones probably are present throughout the area between Hangar Lake and the village because of thawing of the

permafrost by the water in the numerous channels and ponds. No data were obtained to determine the thickness of the surface or active layer of frozen ground.

Data on the deeper ground water body were obtained from drilling the ADH test well (no. 14) and from information received regarding the drilling and water-producing characteristics of the ANHS well (no. 5). The ADH test well was completed on June 8, 1956. The hole was drilled without casing to a depth of 380 feet, where water was encountered. The water rose in the well to a depth of 9 feet below the surface. Coarse gravel and pieces of wood were bailed from the hole. A few days leter (while waiting on casing) a 30-minute bailing test in the uncased well caused a drawdown of about 25 feet at 20 gallons per minute (gpm). The static level before the test was about 16 feet below the surface (see p. 13 for possible explanation of the variable static level). The water level recovered completely within 41 minutes after bailing was stopped. The temperature of the water was 35° F. The well was then cased with 6-inch casing and drilled 10 feet deeper. Very little additional gravel was encountered; evidently there was a layer of gravel and wood on top of the sand. A mechanical analysis (in Alaska Department of Health files) of the material taken from between 380 and 390 feet indicates that about 70 percent of the material will pass a 15-slot screen (slots 0.015 inch wide). No screen has been installed as yet. On the last day of drilling operations, the well was reportedly pumped with a centrifugal pump for 6 hours at 5 gpm with 19 feet of drawdown. The static level of the water before and after the test varied between 9 and 10 feet below the land surface.

The ANHS well (no. 5) was completed in September, 1953 in fine sand with a 9-slot screen. During the original pumping test the well produced 55 gpm with 15 feet of drawdown after 9 hours of pumping. The static level was 38 feet below the surface. Since then, the hospital has used about 700,000 gallons per month. The well has presented several difficulties, however. During the winter of 1953-54, the water in the well column froze; after it had been thawed, the freezing problem was solved by recirculating water and establishing pumping periods at the beginning and the end of each work day. Later that winter, the yield dropped to 38 gpm with a reported drawdown of 195 feet (the depth of the pump bowls). The pump was removed and the well was surged and cleaned. Much "moss"[1/] is reported to have been removed from the well. The pump was reset with the bowls at 235 feet. On pumping, the well again produced 55 gpm, but this time with a reported drawdown of only 157 feet. The writer was unable to obtain accurate information on further trouble with the well, but it was reported (Welfelt, Wm., personal communication, 1956) that the pump was removed one or more additional times to permit cleaning the "moss" out of the well. A static level of 150 feet was reported for the winter of 1955-56; however, a faulty air gage was repaired in May 1956 and the static level was determined to be 40 feet (near the original static level of 38 feet). The drawdown was, reportedly, still about 195 feet.

The chemical analyses (table, p. 19) of water samples from several wells

1/ The "moss" reported may be a form of iron-depositing bacteria (Crenothrix). Its growth may be instigated by contact with air or oxygenated water (possibly the recirculated water?).

indicate that all the samples have the same general character. All the well samples, with the exception of no. 13 which is outside of the immediate Bethel area, are notable for their iron content. Some of the high concentrations of iron reported may be the result of improper sampling procedures, but it seems certain that the water at Bethel contains appreciable amounts of iron. Treatment for iron removal is required on all of the production wells in Bethel at present. It appears that in planning a ground-water supply in this area, the likelihood of obtaining water of high content of iron must be considered. Generally, the water from shallow zones appears to be higher in iron content than the water from deep zones.

The nature and range of water-level fluctuations in this area are not well known. It is reported that the water levels in the wells at the airport fluctuate about 10 feet during the year. This fluctuation is directly related to the stage of the nearby river. The variable static levels reported and measured in the ADH well (no. 14), a nonflowing artesian well, are believed to be related both to changes in river stage and to tidal fluctuations. The confined aquifer was penetrated, at the time when the river was in flood, and the static water level in the well was about 9 feet below surface. A few days later, at the time of the bailing test, when the writer was there, the flood stage had dropped about 5 feet, about the same as the drop in the water level. However, the final water level measured upon completion of the well was reported to be about 9 feet again. The rise and fall in river stage due to floods or tidal fluctuations can cause a corresponding rise or fall of the water level adjacent wells in either of two ways, either as a pressure effect or by actual exchange of water between the river and the aquifer. The daily changes in atmospheric pressure also cause water-level fluctuations and should be considered. A short period of water-level observations might confirm the relation of the fluctuations to the river stage to atmospheric pressure.

SUMMARY

The occurrence of ground water, and the relationship between the permafrost and ground water in the Bethel area are summarized as follows:

The Kuskokwim River has thawed the permafrost wholly, or in part, on the east side of the river.

Permafrost is present to a depth of about 350 feet below sea level on the west side of the river.

The river is thawing the permafrost below the river bed, but the migration of the river is proceeding at a faster rate than the thawing.

Ground water is present, at different places, above, within, and below the permafrost. Near the village, the zone above the permafrost is of little consequence. Although the intrapermafrost zones (talik) are more extensive than the surficial zone, they do not appear to be very promising either. Ample ground water is present at locations east of the river where the subsurface material is saturated and largely unfrozen. The major aquifer west of the river lies beneath the permafrost and is a nonflowing artesian aquifer. The iron content of water from this aquifer is high and removal of iron is required for domestic use.

There is a possibility of a hydraulic connection between the river and the deeper water-bearing zones.

RECORDS OF WELLS AND TEST HOLES IN THE BETHEL AREA, ALASKA

WELL	MATERIALS	THICKNESS (feet)	DEPTH (feet)
1	Alaska Native Health Service Hospital test hole. Altitude about 70 feet. Drilled prior to 1948. Total depth 165 feet. Reported all permafrost.		165
2	U. S. Army test hole. Altitude about 113 feet. Drilled about 1948. Six-inch casing. Total depth 185 feet. Reported no permafrost.		185
3	Civil Aeronautics Administration well. Altitude about 15 feet. Drilled by ANHS test hole driller, prior to 1948. Six-inch casing to 197 feet. Drive point on 4-inch casing driven below 6-inch casing (?) feet. Water level 22 feet below surface.		
	Fine silt (frozen 14-15 feet)	20	20
	Fine sand	89	109
	Medium (?) sand, a little clay at 117, 135 and 165 feet.	88	197
4	U. S. Army (Radar) well. Altitude about 13 feet. Drilled by Clarence Marsh, Bethel, Alaska in 1951. Four-inch casing to 75 feet. Water level 18 feet below surface. Reported yield 66 gpm with 5 feet drawdown.		
	Fine sand and silt	55	55
	Gravel ($1\frac{1}{2}$") and wood chips	20	75
5	Alaska Native Health Service well. Altitude about 70 feet. Drilled by ______ Nicholson, Seattle, Washington; September 1953. Eight-inch casing set to 330 feet, 6-inch set to 403 feet, No. 9 screen from 403 to 423 feet. Reported yield 55 gpm with 15 feet drawdown after 9 hours pumping. Water level 38 feet.		
	Silt, unfrozen	18	18
	Silt, frozen	122	140
	Sand, some gravel and wood, frozen	263	403
	Fine sand and silt, some vegetable matter-unfrozen.	30	433

WELL	MATERIALS	THICKNESS (feet)	DEPTH (feet)
6	U. S. Air Force (10th Radio Relay Squadron) Altitude about 18 feet. Drilled by Clarence Marsh, Bethel, Alaska in 1954. Six-inch casing to 51 feet. Water level 9 feet. Reported yield 133 gpm with 1 foot drawdown after 1 hour pumping.		
	(water)	14	14
	(glacier)	20	20
	(water)	17	51
7	Elmer Nicholson well, Altitude about 17 feet. Drilled by owner, September 1954. Four-inch casing to 120 feet. Water level 6 feet. Well jetted to 149 feet, in 1956.		
	Silt, unfrozen	4	4
	Sandy silt and vegetation, frozen	48	52
	Medium sand, few gravel at 105 feet unfrozen (water)	68	120
	Sand and silt, unfrozen	29	148
	Sand and silt, frozen	1	149
8	Alaska Department of Health test hole No. 1. Altitude about 20 feet. Jetted in June 1955. One and a half-inch pipe to 17 feet. No. 60-slot screen from 17 to 20 feet. Water level about at surface. Reported yield 20 gpm for several hours pumping.		
	Tundra	1/2	1/2
	Tundra and clay, frozen	1-1/2	2
	Silt, grey, unfrozen	8	10
	Silt, grey, frozen	8	18
	Sand, black (water)	2	20
9	Alaska Department of Health test hole No. 4. Altitude about 10 feet. Jetted in June 1955.		
	Tundra and silt	2	2
	Silt, and sand, grey, frozen	13	15
	Fine sand and silt, (water, but would not clear up)	15	30
10	U. S. Public Health Service test hole No. 1. Altitude about 17 feet. Jetted, Fall 1955. Total depth 39 feet. Reported all permafrost.		39
11	Max Leib test hole. Altitude about 15 feet. Jetted, Fall 1955. Total depth 112 feet. Reported all permafrost.		112

WELL	MATERIALS	THICKNESS (feet)	DEPTH (feet)
12	____Schmidt test hole. Altitude about 22 feet. Jetted, Fall 1955.		
	Silt and sand, tan, frozen	50	50
	Silt, and sand, harder	10	60
	Medium sand, blue-grey	25	85
13	U. S. Air Force well. Altitude about 113 feet. Drilled by McInroy Drilling Co., Anchorage, Alaska, in February 1956. Eight-inch casing to 190 feet. No. 12-slot screen from 190 to 203 feet. Water level 61 feet below surface. Reported yield 30 gpm with 12 feet drawdown.		
	Sandy silt	22	22
	Silty sand, frozen	20	42
	Silt, grey	101	143
	Fine sand and sandy silt	47	190
	Silty sand and pea gravel (water)	13	203
	Fine silt, grey	77	280
	Fine silty sand, frozen	98	378
14	Alaska Department of Health well. Altitude about 17 feet. Drilled by G. H. Ramsey, May 1956. Six-inch casing to 390 feet. No screen installed at present. Reported yield 5 gpm with 19 feet drawdown after 6 hours pumping.		
	Tundra, frozen	2	2
	Fine sand and silt, grey, frozen	114	116
	Medium-coarse sand, grey, frozen	34	140
	Fine sand and silt, grey, chunks of wood, frozen	135	275
	Fine sand and silt, frozen	50	325
	Fine sand and silt, wood, frozen	5	330
	Fine-coarse sand, wood, frozen	47	377
	Yellow clay, unfrozen	2	379
	Coarse gravel and wood, unfrozen (water)	1	380
	Medium-coarse sand, some gravel, unfrozen (water)	10	390

Note: Mechanical analysis (see p. 11) indicates this sand is much finer.

TABLE — CHEMICAL ANALYSIS OF WATER FROM WELLS AT BETHEL, ALASKA
ANALYSIS BY GEOLOGICAL SURVEY — RESULTS EXPRESSED IN PARTS PER MILLION EXCEPT pH

WELL NO.	OWNER	DEPTH (feet)	DATE OF COLLECTION	SILICA SiO_2	IRON (Fe)	MANGANESE (Mn)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	POTASIUM (K)	BICARBONATE (HCO_3)	SULFATE (SO_4)	CHLORIDE (Cl)	FLUORIDE (F)	NITRATE (NO_3)	DISSOLVED SOLIDS	HARDNESS AS $CaCO_3$	pH
5	ANS HOSPITAL	423	6-21-55	35	a/ 2.2 b/ .31	0.00	27	4.3	7.1	1.3	108	5.0	3.0	0.0	1.2	137	85	8.1
5	ANS HOSPITAL	423	11-28-55	36	a/ 6.2 b/ 2.3	.11	28	4.3	6.4	1.0	118	2.0	3.5	.2	.5	146	94	7.2
6	U.S. AIRFORCE	51(?)	4-9-54	22	a/ 36. b/ .06	1.0	47	9.4	4.1	2.0	205	.0	3.5	.2	.2	190	156	6.7
6	U.S. AIRFORCE	51(?)	5-25-56	27	a/ 31. b/ .00	1.6	29	4.3	2.7	1.4	119	2.8	2.0	---	.0	130	90	7.0
8	ALASKA DEPT. OF HEALTH	21	6-11-55	37	a/ 9.9	.00	20	4.4	2.6	1.3	84	4.5	1.5	.0	4.6	117	68	6.9
HANGAR LAKE	NEAR WELL #8	---	6-11-55	4.0	a/ .29 b/ .16	.00	6.4	1.9	1.1	1.0	8	20	1.0	.0	.2	40	24	6.6
13	U.S. AIRFORCE	202	5-25-56	30	.00	.09	32	3.6	3.9	.4	117	6.0	2.5	---	.0	136	95	7.2
14	ALASKA DEPT. OF HEALTH	390	6-7-56	35	a/ 17 b/ .00	.04	33	6.4	8.5	1.7	144	5.7	7.0	.0	.0	168	109	7.0

a/ Total
b/ In Solution

Date Due
